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POTATO BLIGHT FORECASTING INVESTIGATION IN ENGLAND AND WALES, 1950–52

Contribution from the Conference of Plant Pathologists, National Agricultural Advisory Service, compiled by E. C. Large of the Plant Pathology Laboratory, Harpenden, Herts

Until 1950, press warnings to farmers of the imminence of general outbreaks of Potato Blight, *Phytophthora infestans* (Mont.) de Bary, in England and Wales, were based solely upon notifications of the first records in each season, which were sent in by N.A.A.S. plant pathologists to the Plant Pathology Laboratory by telephone and telegram. For reasons which can now be more clearly seen, and which are discussed below, this simple procedure was more effective than might have been expected in giving warnings in sufficient time for protective spraying. It had long been felt, however, that some practicable means was needed whereby meteorological observations could be employed to reinforce, if not entirely to supplant, the evidence of first records as a basis for a warning service.

Such a system was established in Holland following the work of van Everdingen (1926), and an attempt was made by Wiltshire (1931) to test the validity of the Dutch rules for England and Wales by correlating weather data and known dates of outbreak of blight for a number of districts in the years 1921–7. The work was then taken up by Beaumont, who, as a result of detailed studies at Seale-Hayne Agricultural College in Devon over the eleven years 1929–39, was able to effect a simplification of the Dutch rules, and to show that the critical conditions, generally preceding the outbreak of Potato Blight by from 7 to 21 days, are :

Temperature not less than 50°F. and relative humidity not below 75 per cent for at least 48 hours.

The Beaumont temperature-humidity rule was also tested by Grainger (1950) in the west of Scotland for the five years 1944–48, and forecasts based upon the occurrence of Beaumont periods, after the last days of June, were found valid each year. Beaumont had clearly foreseen that for each district there would be a time in the season before which his critical periods would not be followed by outbreaks of blight, and, for Ayrshire, Grainger found this " zero date " to be the end of June.

In 1949, weather stations in Scotland and in the south-west of England were already advising plant pathologists of the local occurrence of Beaumont periods to assist them in their work on potatoes. Mr. L. P. Smith of the Agricultural Branch of the Meteorological Office then suggested that this help might be extended, and the suggestion was welcomed by the N.A.A.S. conference of Plant Pathologists. As a result it was decided to investigate the possibilities of blight forecasting, by the Beaumont rule, throughout England and Wales, utilizing for this purpose a network of about forty synoptic weather stations which were already taking the necessary hourly observations of temperature and humidity. This report summarizes the results of the first three years of the work.

METHOD OF INVESTIGATION

The meteorological officers at the participating synoptic weather stations informed the plant pathologists in their regions immediately Beaumont periods had occurred, and the plant pathologists, for their part, searched for the first

appearance of blight in the zones served by the stations. The original plan was for the search to be made *in the immediate vicinity* of the weather stations. This was quickly modified in practice when it was realized that there were few potatoes in the near vicinity of some of the stations, and that the practical matter at issue was to determine to what extent warnings based on critical conditions occurring at the meteorological stations would be valid *for the potato-growing areas*. A general search for first outbreaks of blight was therefore made in all parts of the country, and at the end of the season the sites of the outbreaks were plotted on a large map and their distances and bearings from the weather stations were measured. The dates of outbreak were then charted on a time scale against the critical periods at the nearest weather stations (Figs. 2, 4 and 7).

LOCATION OF THE WEATHER STATIONS

The weather stations participating in the investigation during the whole or part of the three years, were as follows :

		Altitude (feet above sea level)
Northern		
ACKLINGTON	Northumb	138
MIDDLETON	Durham	115
SILLOTH	Cumb	25
Yorks & Lancs		
LEEMING	Yorks N.R.	105
DISHFORTH	Yorks N.R.	106
DRIFFIELD	Yorks E.R.	65
CHURCH FENTON	Yorks N.R.	27
SQUIRE'S GATE	Lancs	33
SPEKE	Lancs	80
MANCHESTER	Lancs	230
North Wales		
VALLEY	Anglesey	32
West Midlands		
SHAWBURY	Salop	235
*NEWPORT	Salop	211
ELMDON	Warwicks	326
*WELLESBOURNE	Worcs	153
DEFFORD	Worcs	28
South Wales		
PEMBROKE	Pemb	40
LLANDOW	Glam	145
South-West (Bristol)		
RISSINGTON	Glos	740
FILTON	Glos	192
LYNEHAM	Wilts	455
BOSCOMBE	Wilts	414
South-West (Exeter)		
CHIVENOR	Devon	20
EXETER	Devon	100
PLYMOUTH	Devon	86
ST. EVAL	Cornwall	345
East Midlands		
FINNINGLEY	Notts	28
WADDINGTON	Lincs	235
WATNALL	Notts	389
COTTESMORE	Rutland	452
Eastern		
*TERRINGTON	W. Norfolk	13
WEST RAYNHAM	Norfolk	250
MILDENHALL	W. Suffolk	15
OAKINGTON	Cambs	40
CRANFIELD	Beds	348
FELIXSTOWE	E. Suffolk	10
*ROTHAMSTED	Herts	420
*WRITTLE	Essex	105
BOVINGDON	Herts	516
South-East (Reading)		
ABINGDON	Berks	210
BENSON	Oxon	215
FARNBOROUGH	Hants	226
SOUTHAMPTON	Hants	39
ODIHAM	Hants	400
TANGMERE	W. Sussex	53
HURN	W. Hants	33
South-East (Wye)		
WEST MALLING	Kent	309
MANSTON	Kent	135
LYMPNE	Kent	341

* Supplementary station.

The stations are listed according to the N.A.A.S. provinces in which they were situated, but a number of stations near provincial borders reported to the plant pathologists in two or more provinces.

Potato Blight Forecasting

The map (Fig. 1) shows the situation of the stations in relation to the distribution of potato crops in England and Wales. The map was prepared from the figures for 1950 county potato acreages, supplemented by reference to the Agricultural Atlas for England and Wales (1932) for the approximate distribution within counties. The potato acreages change each year, but in the main the distribution of the crop is determined by unchanging physical features of the land, so that the indications given are near enough for present purposes.

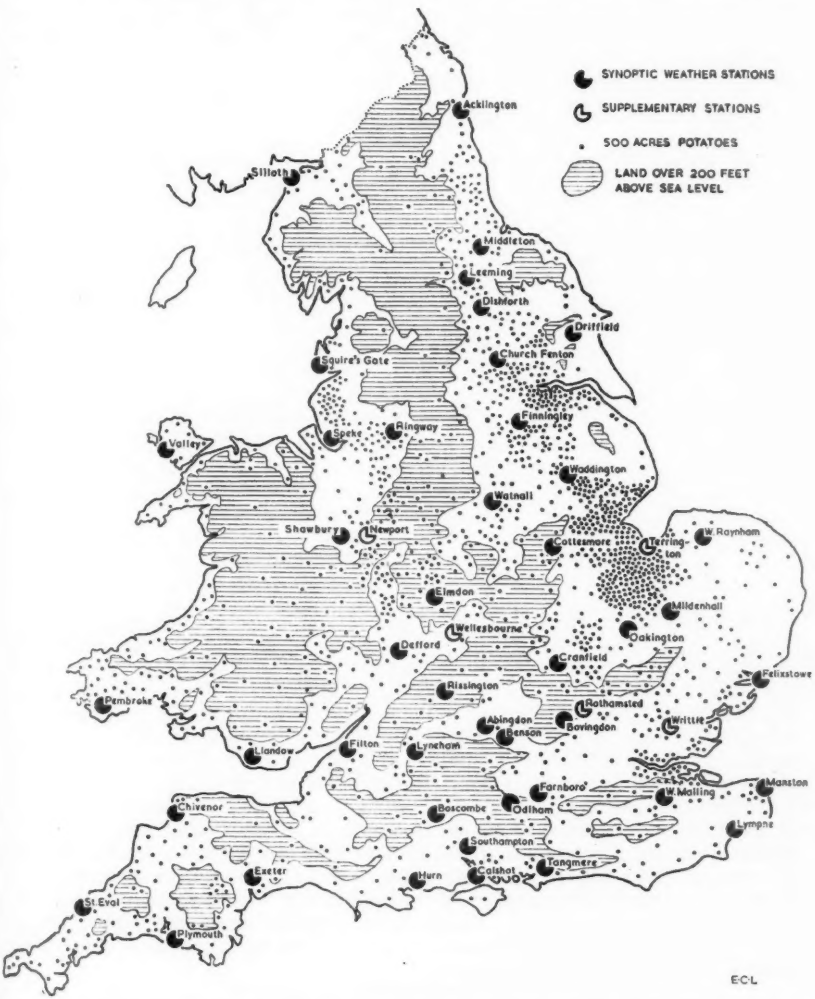

Fig. 1. Location of weather stations participating in the forecasting investigation, 1950–52, in relation to the approximate distribution of potato crops in England and Wales, and to land over 200 feet above sea level.

(56525) A**

As most of the potatoes in the country are grown on land less than 200 feet above sea level, the 200-foot contour is plotted on the map, and all land above that altitude is shown shaded. The map shows that many of the weather stations in the existent network were suitably located for serving potato-growing areas, but some, on high ground or in the rain shadow of mountains, were not so well situated for this purpose.

A few changes were made in the network of synoptic stations in 1951 and 1952, and to make good the lack of a station to serve the important potato-growing area around the Wash, recording instruments were installed at Terrington Experimental Husbandry Farm. Similarly, to fill other gaps, instruments were installed at Writtle (in co-operation with the Essex Institute of Agriculture), and at Newport, Salop (in co-operation with the Harper Adams Agricultural College).

The critical conditions often persisted for more than 48 hours, and the meteorologists therefore notified the actual starting and finishing date and hour of each period, so that its duration could be shown on the chart. In 1951 and 1952 they also advised " near-critical " periods during which the critical conditions were broken by not more than one hour in a day. This service was given each year from May 1 to September 30 in the south-west, and from June 1 to September 30 in all other parts of the country. The hourly readings at the synoptic stations were made on instruments in screens approximately four feet above the ground ; the screens were not in potato fields but for the most part in open surroundings over grass. These conditions of recording were not the same as those in the original experiments on which the Beaumont rule was based, for then the recording instruments were in the potato crops ; but the whole purpose of the co-operative investigation, essentially empirical in its nature, was to ascertain to what extent Beaumont periods occurring in the screens at the weather stations would serve for a practical forecasting scheme.

DEFINITION OF A BLIGHT " OUTBREAK " AND THE OBTAINING OF PROGRESS RECORDS

The British Mycological Society's key, already reproduced in this JOURNAL (Large, 1952), was used by the plant pathologists and the collaborators throughout the investigation. Blight at the 0·1 per cent stage in a potato *field* was taken as constituting an " outbreak ". Blight at earlier stages than this was found from time to time, for example, where there was only a single small lesion on a single plant ; and blight at more advanced stages was sometimes found very early on volunteer plants on clamp sites or in early potatoes in gardens. These occurrences were carefully noted but not regarded as outbreaks. In the course of the surveys many crops were not seen for the first time until blight on them had advanced beyond the 0·1 per cent or " outbreak " stage. The use of the key enabled the actual state of blight on such crops to be recorded, and therefore for estimates to be made of starting dates from evidence of progress. Such estimates were not used in the critical consideration of the forecasting performance of the stations, but, in conjunction with a great many " nil " reports, they were of much value in the approximate zoning of the whole country for general date of outbreak.

It is the general date of outbreak that is of importance for regional spray warnings ; but it is the subsequent course of development of blight, rather than the mere date of outbreak, that determines the extent of loss caused by the disease on unsprayed crops in any region or season. For this reason, and to

extend the scope and value of the blight surveying, fortnightly assessments of the progress of blight on a limited number of crops in each region were made with the aid of the key each year throughout the growing period. Thus curves were obtained which defined the regional and seasonal courses of the blight epidemics. The uses of these curves, a representative few of which are given under the maps, Figs. 3, 5 and 6, have already been discussed in this JOURNAL (Large, 1952). The frequent persistence of blight at the outbreak stage for some weeks, as revealed by the progress curves, is of particular significance in forecasting work, for it suggests that " date of outbreak " is often more truly represented by a range in time, than by any meticulous single date.

ORGANIZATION OF THE FIELD SURVEY

By enlisting the aid of many collaborators, and taking advantage of visits to potato fields for other purposes plant pathologists obtained over a thousand blight outbreak and progress records throughout the country each year. In all provinces extensive use was made of potato variety, manurial, spraying and haulm destruction trials as observation sites. Almost every district advisory officer and a number of horticultural advisory officers in the N.A.A.S. contributed observations, as did all the crop recorders of the National Institute of Agricultural Botany. Experimental Husbandry Farms, Agricultural Colleges and Farm Institutes joined in the work, and important contributions were made from research in progress at Rothamsted.

The " Blight Notification Slips ", issued to collaborators, called for the following information :

Date of Observation : Variety : County :

Name and address of farm :

PERCENTAGE OF BLIGHT ON HAULM (by key provided) Unsprayed : Sprayed :

Date of last observation, if any :

Date of any spraying or dusting not previously reported :

State of growth of haulm :

The plant pathologists noted the data as the slips came in, and thus had a day-to-day record of the progress of blight in their areas ; after this abstraction the slips were forwarded at once to the Plant Pathology Laboratory at Harpenden where they were indexed, and the progress of blight over the whole country was charted, side by side with the observations from the meteorological stations. The whole of this information was used in each year's issue of advice to farmers through the press and the B.B.C.

EXPERIENCE IN 1950

1950 was a " blight year ". In the south-west, blight starting in the first half of July was not unusually early ; but over the whole of the rest of the country, south of a line from the Humber to Pembroke, there was an unusually warm,

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wet and humid period in the first week of July, and with the two following weeks also mild and wet, there was a general outbreak in the second half of the month. The decay progressed steadily through a showery August, and with heavy rain at the end of the month, most of the unsprayed haulm was dead by early September. In the northern half of the country there were general outbreaks in early August, except in the north-eastern coastal strip from the Yorkshire Wolds to the Scottish border. Fig. 2 shows how the first outbreaks were related to the Beaumont periods occurring at all the stations, and Fig. 3 shows the zoning of the country for date of outbreak, summarizes the forecasting performance of the stations in a graphical way, and gives below the progress of blight in a number of regions.

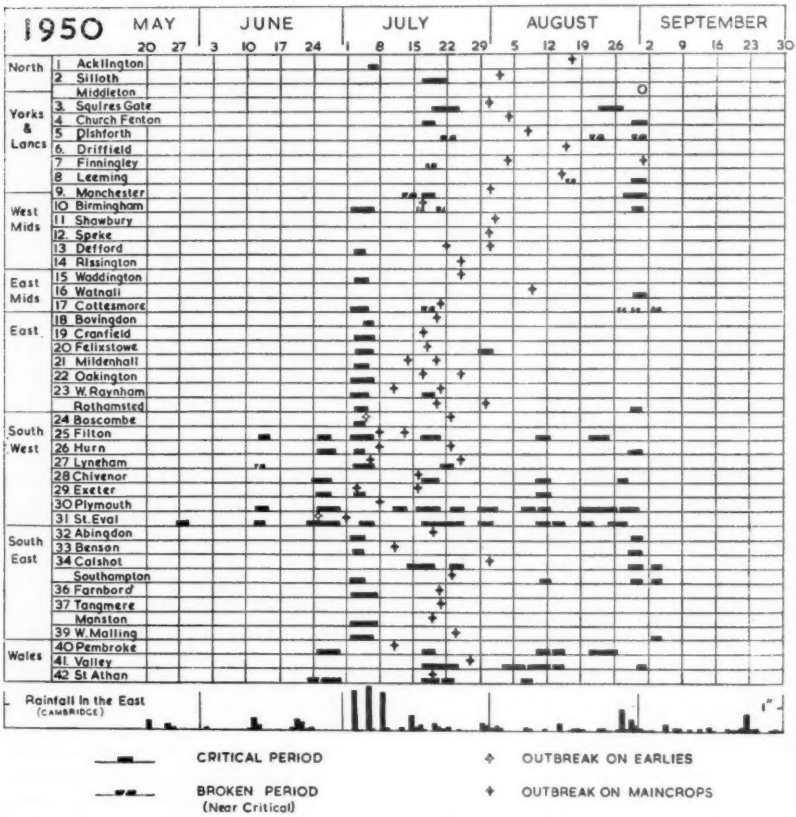

Fig. 2. Blight outbreaks in relation to Beaumont periods at all stations in 1950.

In 1950, when the blight epidemic was early enough to justify the cost of preventive spraying of maincrops throughout the south of the country, the forecasts based on the occurrence of Beaumont periods at nearly all the stations were valid for their areas. In the whole of the zone in which outbreaks occurred

before mid-August, only five stations did not have first critical or near-critical periods 7 to 21 days before the outbreak. These stations were Speke, Shawbury, Watnall, Rissington and Tangmere. In the north-eastern zone, in which

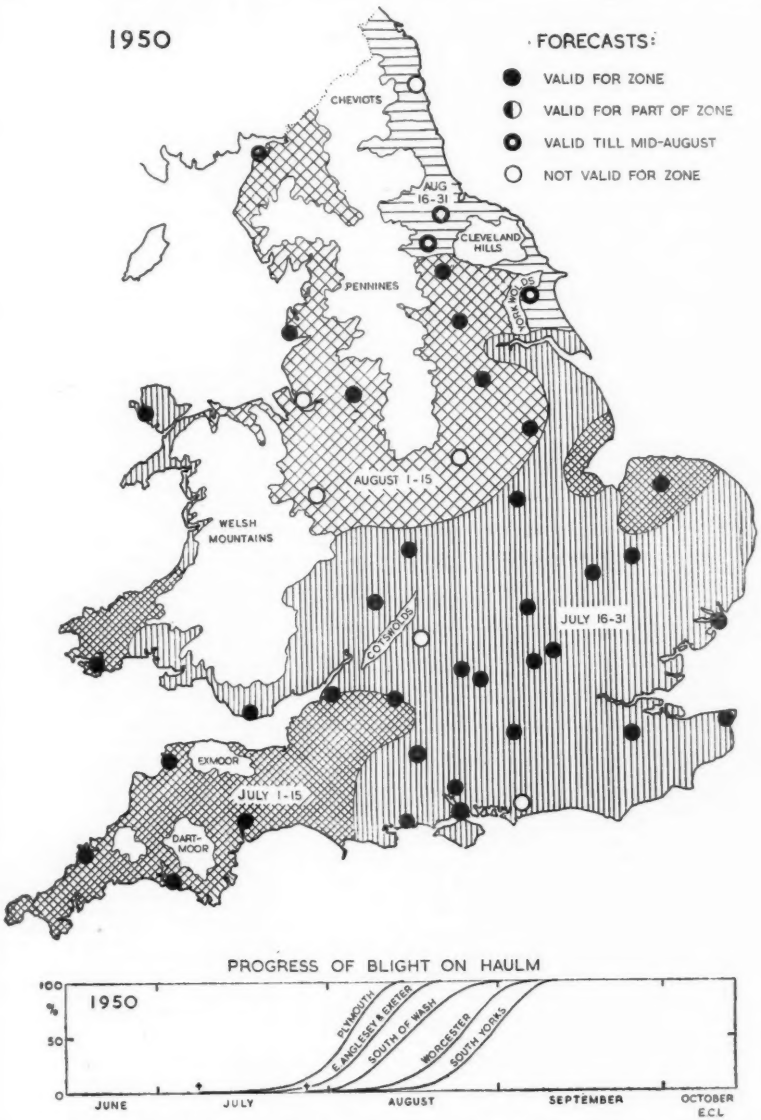

Fig. 3. Zoning of England and Wales according to date of blight outbreak, and validity of forecasts at all stations in 1950, with progress of blight on haulm in six districts.

(56525) A** 3

outbreaks did not occur until after mid-August, Middleton, Leeming and Driffield scored a partial success, in that they did *not* have critical periods before that date, and therefore rightly indicated no need for preventive spraying, but they failed in that they did not have critical periods preceding the outbreak of blight in late August. Acklington, however, had a critical period in early July, which was premature and invalid for the zone.

EXPERIENCE IN 1951

1951 was not a " blight year ". In most regions the outbreak was a month later than in 1950 (compare progress curves for 1950 and 1951 in Figs. 3 and 5). Even in the south-west and the west coastal belt there was little need for preventive spraying. The growth of the potatoes was retarded owing to low soil temperatures in the spring, and a dry June ; July was dry ; and August was dull with only intermittent spells of rain. In late August it seemed probable

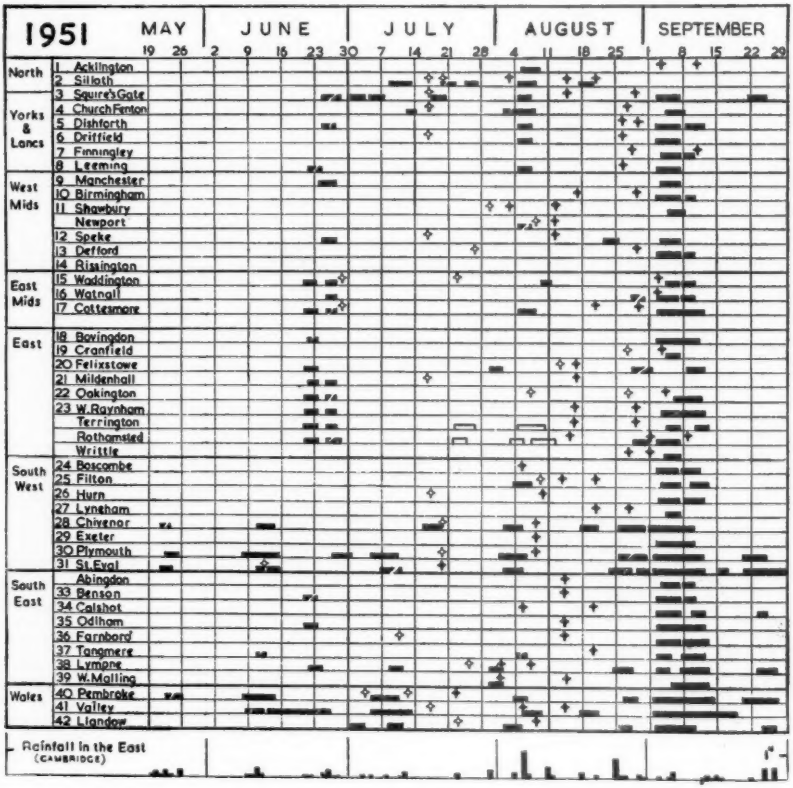

Fig. 4. Blight outbreaks in relation to Beaumont periods at all stations in 1951.

that there would be a slow and lingering end-of-season progress of blight on haulms remaining green longer than usual. In early September, however, an exceptionally warm and humid air mass covered the country for a week or more,

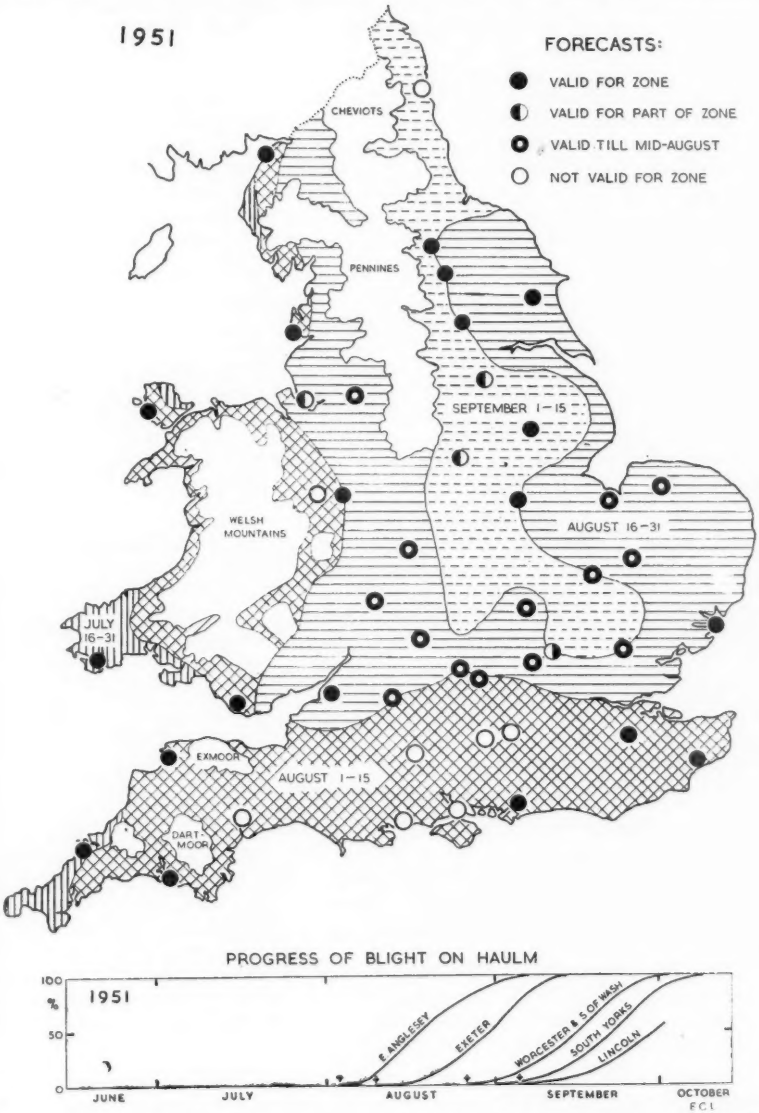

Fig. 5. Zoning of England and Wales according to date of blight outbreak, and validity of forecasts at all stations in 1951, with progress of blight on haulm in six districts.

(56525) A** 4

the soil was wet, rain continued, and the blight, then making rapid progress in all districts, killed off the unsprayed tops in good time for lifting.

A flush of warning periods occurred in the last week of June (Fig. 4), but this was followed only by scattered outbreaks on earlies in July. The general outbreak on maincrops was heralded by the second flush of warning periods in the first week of August. The map (Fig. 5) makes it clear that what was chiefly tested in this year, elsewhere than in the west coastal belt, was the forecasting of late outbreaks by the Beaumont rule. This was not so successful as the forecasting of the July outbreaks in 1950. Discounting the June warning periods as before " zero date ", especially in view of the backwardness of the potato crops, most of the Midland and eastern stations had no warning periods until September. Forecasts based on this would have been correct, in that they would have indicated no need for preventive spraying, but incorrect in that they would not have foretold the outbreaks after mid-August.

The probable explanation of the partial failure was that border-line humidity conditions prevailed over the whole of the Midlands and the east of the country in early August 1951, and that in these circumstances there were Beaumont conditions in the potato crops, but not in the screens at many of the synoptic stations. That this was the true explanation was borne out by the findings of Mr. J. M. Hirst of Rothamsted, who, in connection with his research on blight and the ecoclimate of potato fields, had recording instruments both in screens and in the crops at Rothamsted and Terrington. At both these stations Beaumont periods occurred in the crops but not in the screens during the relevant period, as indicated in Fig. 4.

Although the humidity conditions occurring in the screens at Midland and eastern stations in 1951 did not give warning of the outbreaks occurring in the second half of August—too late for preventive spraying—they certainly did not fail to indicate weather very favourable for the rapid *development* of blight in early September. Beaumont periods indicate not only conditions favouring the outbreak of blight, but also, later in the season, conditions favouring its rapid epidemic increase and spread. Thus the principal flush of warnings in 1951, occurring as it did in early September, had an important significance, apart altogether from forecasting outbreaks : it truly indicated a rapid killing-off of the haulm by blight, rendering chemical or mechanical haulm destruction largely superfluous.

EXPERIENCE IN 1952

As it was seen in 1951 that humidity conditions giving critical periods in the crops could be expected from time to time to give critical periods in the screens at some, but not all, of the synoptic stations, it was decided to explore the possibilities of an " operations chart " method of working : that is to say, of basing regional forecasts not so much on the occurrence of critical periods at individual stations, but on the indications of the network of stations as a whole. For this purpose the chart (Fig. 7) was kept up to date, day by day, with both warnings and first outbreaks, and a copy of it was issued by the Plant Pathology Laboratory to all the provincial plant pathologists immediately after each " flush " of warning periods had occurred.

1952 was a " blight year " in west coastal regions, but not elsewhere. The progress curves (Fig. 6) show that there was a remarkably wide range in the dates of the epidemic according to region. In west Cornwall the haulm was half dead by the end of July ; in Lincolnshire and south of the Wash many crops were still free from blight at the beginning of October. Owing to high

spring temperatures and average rainfall the crops were, in general, well forward in June. On the west coast, from Cumberland to Cornwall, there were critical periods of long duration recurring over the major part of the growing period.

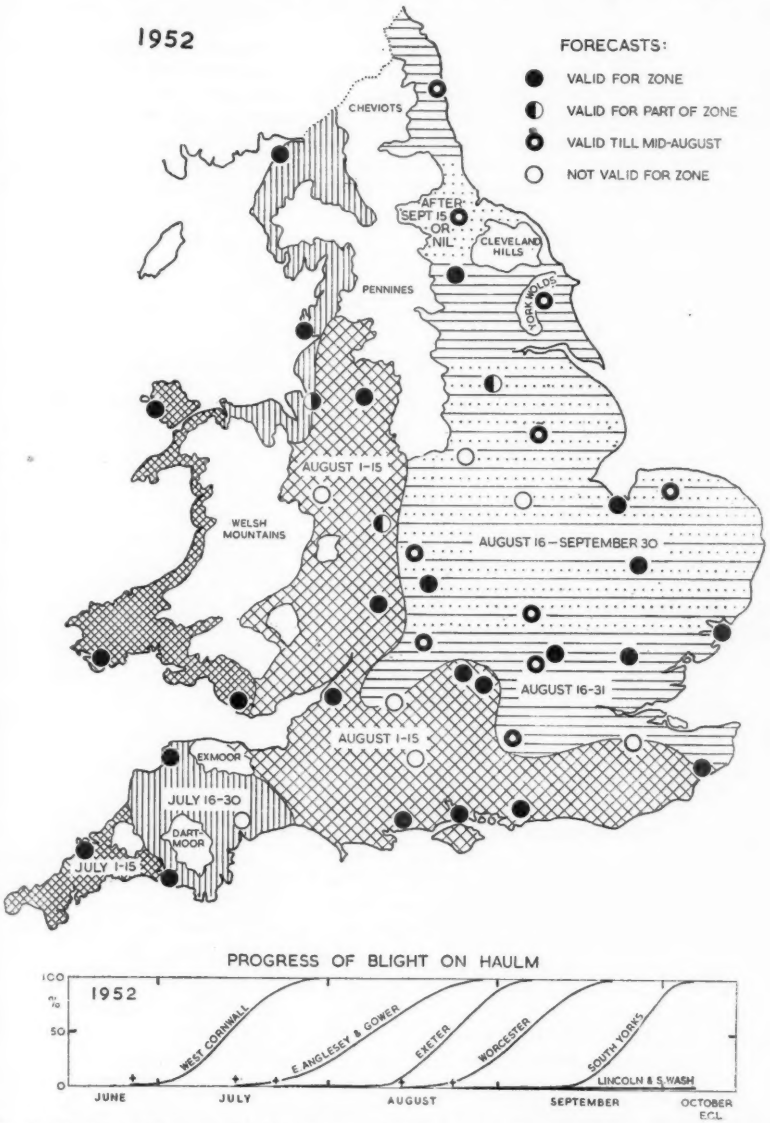

Fig. 6. **Zoning of England and Wales according to date of blight outbreak, and validity of forecasts at all stations in 1952, with progress of blight on haulm in eight districts.**

Elsewhere in the country there was a minor flush of warning periods about mid-June (Fig. 7,) and the first " operations chart " sent out after this indicated some possibility of outbreaks on earlies and the more forward maincrops in early July. There were, in fact, a few outbreaks on earlies at that time, but for maincrop varieties the June warnings proved once more to be before " zero date ".

July was dry, with an absolute drought in the south and east. Later there was much rain and a second " flush " of warning periods occurred in the first ten days of August. The operations chart then sent out indicated a general outbreak of blight on maincrops about mid-August, and this forecast was correct. The potatoes which had suffered from the drought revived to some extent after the rain, but many crops were already yellowing off when blight started, and with dry weather at the end of August, followed by a very cold

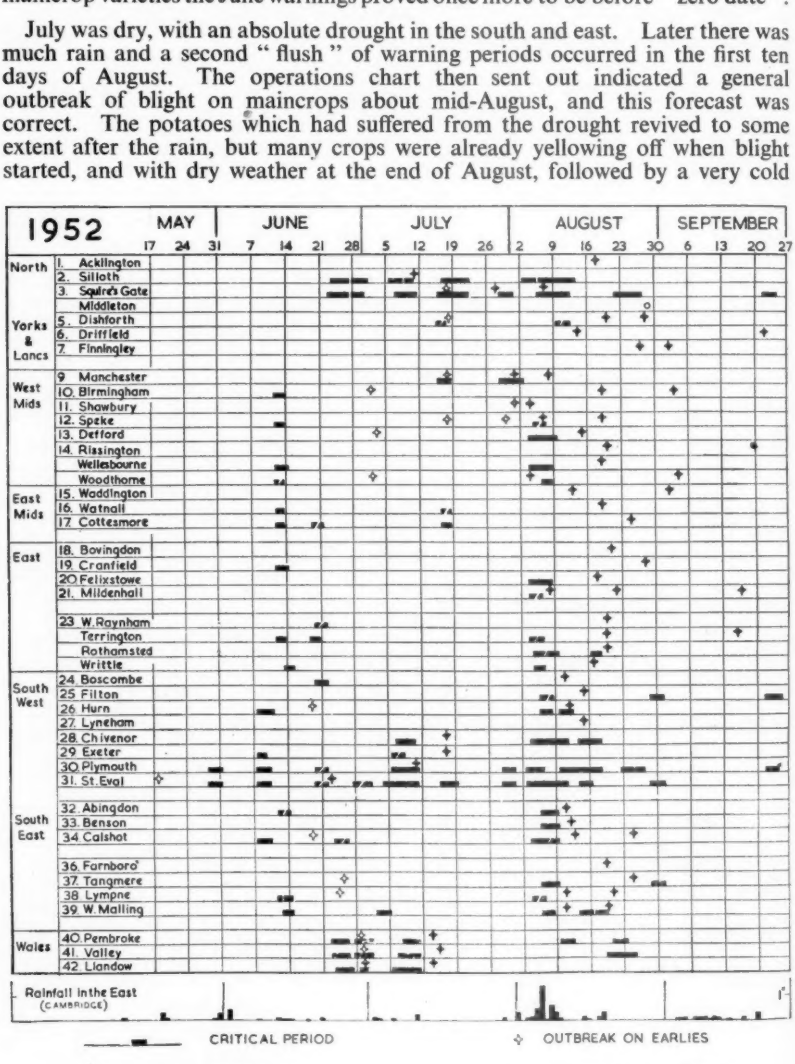

Fig. 7. Blight outbreaks in relation to Beaumont periods at all stations in 1952. The completed " operations chart ".

September, blight in some areas made little progress and the crops remained free from blight to the end of the season.

Of the forty-four stations used in 1952, only three (Watnall, Cottesmore and West Malling) had Beaumont periods on which premature warnings might have been based ; four others did not have periods to give warnings of outbreaks before mid-August, and therefore also " failed " ; three gave warnings that were valid for only a part of their zone ; no less than twenty-four had fully valid warning periods for the whole of their respective zones ; and ten, rightly, had no warning periods for outbreaks before mid-August, but " failed " partially in that they had no periods giving warnings of outbreaks after that date. The positive warnings given by the network of stations as a whole were sufficient for forecasting the general dates of outbreak correctly in all zones by the operations chart. This is shown by the map (Fig. 6) and by the chart itself (Fig. 7).

GENERAL CONCLUSIONS

The investigation, so far as may be seen from experience in one " blight year " and two years in which blight was generally late except in the west, has shown that notifications of Beaumont periods occurring in screens at the synoptic weather stations enable broad regional forecasts of date of blight outbreak to be made successfully, for all regions of England and Wales, provided that the indications from the whole network of stations are taken into account by an operations-chart method of working.

A few of the synoptic weather stations, by reason of their altitude, proximity to urban areas or other topographical circumstances, have been found to be of little value in the network except, perhaps, as indicators of very local conditions or extreme general conditions. These stations include : Shawbury, in the rain shadow of the Welsh mountains ; Bovingdon, over 500 feet up on the Chilterns ; Rissington at 740 feet on the Cotswolds ; Lyneham at 455 feet between the Cotswolds and the Marlborough Hills ; and Driffield on the southern slopes of the Yorkshire Wolds. As will be seen from Fig. 1, these stations have few potato crops in their immediate locality. A few other stations, notably Finningley and Speke, may be expected to give indications which are valid only for a restricted part of their zone. Supplementary stations are needed in some areas.

It was found in each year that outbreaks on some of the more forward maincrops often preceded the general outbreak. It was also found that blight, especially when checked by dry weather, very frequently remained at the 0·1 per cent or " outbreak " stage for some weeks. These observations went far to explain why the old system of basing press notices on records of first outbreaks was generally, if not invariably, successful in giving warnings in time for effective preventive spraying.

The operations-chart method of working takes into account both the meteorological warnings and the evidence of first outbreaks. The charts should be interpreted in the light of the zoning maps which embody the experience of past seasons, and regional forecasts should be supplemented by detailed local knowledge.

There has been a strong indication that the " zero date "—before which Beaumont periods are not followed by general outbreaks on maincrops—is about the last week in June elsewhere than in the south-west, west coastal areas,

and possibly round the Wash ; but experience in more seasons is necessary before " zero dates " for all regions can be stated with confidence, and the forwardness of the potato crops should be taken into account in judging the possible validity of early warnings.

There has been an indication that forecasting by Beaumont periods occurring in screens at synoptic weather stations is more reliable in July and early August—when a spray warning service is needed—than earlier or later in the season. This is probably explained by a wider divergence between the humidity conditions in the screens and in the crops over these periods.

The progress curves for blight obtained in the course of the investigation have shown that there is no constant relation between the date of outbreak of blight and the date at which rapid destruction of the haulm begins. Cook (1949) has developed a method of forecasting in the U.S.A. which has regard rather to the destructive course of blight than to date of outbreak. This method is based on a study of the cumulative rainfall in each region in " blight " and " no blight " years. The limiting conditions for the development of blight in this country and in the U.S.A. may differ widely, but cumulative rainfall curves similar to those of Cook have been plotted against blight progress for all stations in 1950, 1951 and 1952. Curves for more years are required before the bearing of cumulative rainfall on blight development in England and Wales can become apparent.

Since the inception of the present work in England and Wales, Post and Richel (1951) have published the results of an investigation, carried out over a number of years, to ascertain whether the use of the Beaumont rule, in place of the van Everdingen rules, could lead to an improvement in the warning service in the Netherlands. They concluded that there is every ground for attributing reasonable reliability to forecasting by temperature-humidity rule, using instruments in screens at synoptic weather stations. To avoid the necessity for hourly observations, however, they have proposed that under their conditions a critical period should be taken as one in which the relative humidity averages 82 per cent or more during two consecutive days (computed on observations at 8 a.m., 2 p.m. and 7 p.m. G.M.T.) while, on one of the days, the minimum temperature is 50°F. or more. Forecasting work, using different humidity criteria, is now also under way in Eire (Bourke, 1952).

The investigation in England and Wales is continuing, and possible refinements of the Beaumont rule, as well as effects of weather conditions on blight development after the outbreak, are being studied.

The Conference of Plant Pathologists takes this opportunity of thanking all those members of the Meteorological Office who have recorded, provided and helped in the analysis of the weather data ; and all those district advisory officers, crop recorders, farmers, research workers and members of Farm Institute and Experimental Husbandry Farm staffs who have taken part in the field work on Potato Blight.

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ROOT ROT OF BRASSICAS CAUSED BY *PHYTOPHTHORA MEGASPERMA*

by A. G. ROBERTSON AND L. OGILVIE

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A root rot of savoy and winter cauliflower was observed at Long Ashton, Somerset, in March 1949, and of marrowstem kale at Gloucester in October 1950. On savoy and winter cauliflower the lower leaves showed progressive purpling from the margins ; they soon wilted and were either shed or they remained lying in a rosette round the plants. Leaf shedding was pronounced in savoy, leaving a flabby ball which was often rotted by *Botrytis cinerea* Fr. The stems were also soft and flabby. The symptoms on kale were rather similar. Infected plants could be readily pulled up and they showed a considerable sloughing of the cortex and finer lateral roots. Adventitious roots sometimes developed above the lesions and so maintained turgidity for a time. Infected plants were growing in heavy clay with poor drainage.

The tissues near the margins of the root lesions were blackened and contained abundant non-septate hyphae. Isolates of the fungus made rapid growth on malt agar, and quickly produced oospores. Identification of the fungus as *Phytophthora megasperma* Drechsl. was confirmed by Dr. C. J. Hickman. The same species has been reported by Tompkins, Tucker and Gardner (*J. agric. Res.*, 1936, **53**, 685–92) as causing a similar disease of cauliflower in North America.

In inoculation tests made in the spring of 1949, winter cauliflowers (variety Snowball) were planted in twelve pots with sterilized soil. At the second-leaf stage on April 2, six of the pots were inoculated with chopped pieces of a malt agar culture of the *P. megasperma* obtained from the winter cauliflower at Long Ashton. The other six pots were left as controls. All twelve pots were stood in three to four inches of water in a cool greenhouse until April 26, when the plants in five of the six inoculated pots were showing signs of purpling accompanied by cortical rotting. *P. megasperma* was recovered from all five of these plants.

ALTERNARIA BRASSICICOLA ON SUMMER CAULIFLOWER SEED

by FRIEDA C. SCHIMMER

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The occurrence of Dark Leaf Spot, caused by *Alternaria brassicicola* Wiltshire (Wiltshire, 1947) on brassicas—particularly on seed crops—in this country is well known, but the extent of the damage which can be caused by seed infection is often not appreciated. The disease has been studied intensively abroad, especially in Denmark (Nielson, 1933 ; Neergaard, 1945).

The cultivation of seed crops of summer cauliflowers under glass has been investigated at Wye College since 1950. Each year, but particularly in 1950, the inflorescences and pods were severely attacked by *A. brassicicola*, and the seed also became infected. Using the Ulster method (seeds put on 2 per cent malt agar) infection was 96–100 per cent in 1950, 31 per cent in 1951, and 63–77 per cent in 1952. A number of other fungi were occasionally found on the surface of the seed—*Botrytis* sp. was particularly abundant in 1951—but none of them were apparently active in attacking the seedlings.

Seeds germinated in petri dishes lined with moist filter paper showed the characteristic small, black, necrotic streaks and spots on the cotyledons and stems of the seedlings (Plate II, 3) after about four days. Under the very moist conditions these seedlings were soon overgrown by the fungus (Plate II, 1) and killed. When the seeds were sown in John Innes compost, as in commercial practice, there was much less obvious damage. For example, on a sample which showed 91 per cent infection when tested by the petri dish method, there was only 10 per cent infection and 10 per cent failure to emerge when the germination was in soil. With germination in compost, however, the severe " wire-stem " effect noted by Rangel (1945) was frequently observed (Plate II, 2) particularly at transplanting, and sometimes 76 per cent of the plants were affected. There was no evidence of *Corticium solani* on these plants, and the effect was not found on seedlings from seed given the hot-water treatment described below.

The relative effectiveness of many different seed disinfectants has been investigated abroad ; it is generally agreed that a hot-water treatment (see Nielson, 1936) is the only really effective method, although others have sometimes given good results. My own observations confirm these conclusions :

Treatment	Percentage Infection		
	1950	*1951*	*1952*
Control, untreated	96	31	60
Hot-water treatment. 122°F., 18 min.	1	0	0
Mercuric chloride, 0·1 per cent, 10 min. ..	23	0	20
TMTD dust	40	—	—
Organo-mercurial dust	14	—	—
Mercuric chloride, as above, with wetter ..	15	—	—

During the course of the work at Wye it has been repeatedly observed that dying parts of the flower head readily become colonized by *A. brassicicola*, and thus provide a source of inoculum close to the developing fruit. It is hoped that the studies in progress on the nutrition of the crop may reveal means by which much of this dying material may be eliminated.

Thanks are due to Dr. I. Selman for the photograph of the "wire-stem" effect, to Mr. W. F. Buck for that of necrotic streaking and spotting, and to Mr. E. C. Large for the photomicrographs of spores.

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GREEN PETAL—A NEW VIRUS DISEASE OF STRAWBERRIES

by A. F. POSNETTE

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The Green Petal disease was first seen by me in May 1951, in a two-year-old field of Auchincruive Climax near Sutton Valence, Kent. Only two affected plants were found among approximately 7,000 ; it was noticed that their runners also showed symptoms. Later in the same year the disease was recorded in other fields in Kent, and reports were received of its occurrence in other counties. The number of affected plants in any field was usually less than ten, and these were scattered single plants. Many more cases were found in 1952, both on Climax and on Cambridge Seedlings, and the prevalence of the disease appears to be increasing.

The most characteristic symptoms on Auchincruive Climax occur on the flowers. The sepals are enlarged and petals are dwarfed and pale green. Varying degrees of sterility occur ; some flowers develop the normal number of ovules, but usually few achenes are formed and some flowers are sterile. Fruit seldom ripens on affected plants. The achenes stand out from the receptacle, which shrivels before maturity, and the dried inflorescences are a useful symptom in field diagnosis (Plate I, 1).

The mature leaves first turn a dull yellowish or olive green, and later a bright red. The red colour of the old leaves is conspicuous in August and September. The foliage feels stiff and harsh. New leaves formed after infection are extremely dwarfed, slightly cupped, with the main veins and margins yellow. The contrast between the long petioles of the old leaves and the short petioles of the young leaves is extreme (Plate I, 2). Soon after the appearance of the small leaves, the older leaves wilt and shrivel. The whole plant may collapse and die in July or August, but sometimes there is a temporary recovery in September with the formation of secondary crowns with minute leaves. It is believed that those Climax plants which show flower symptoms in June are

almost invariably killed before the following October. The stolons of infected plants are short and thickened, and the young " runner " plants extremely dwarfed.

SYMPTOMS ON OTHER VARIETIES

Full symptoms have been observed on Cambridge 422 (Favourite) and other varieties in the Cambridge Seedling series, some of which seem to be more tolerant than Climax. Similar foliage symptoms and collapse have been seen on Huxley and Royal Sovereign, but the diagnosis has not yet been confirmed on flower symptoms, and transmission tests with these varieties are not complete.

TRANSMISSION

In 1951, affected Climax plants lifted from the field and transferred in pots to the glasshouse invariably died before graft unions could be established. In May 1952, two virus-free Climax plants were taken to an isolated special stock bed and stolon-grafted to an affected plant *in situ*. Four weeks later the runners were cut from the affected plant, and the test plants, with grafts attached, were returned to the glasshouse. Symptoms developed on the test plants ten weeks after grafting. Graft transmission has also occurred from a Climax plant transferred to the glasshouse in the early stages of infection, and transmission to Climax plants was obtained in the glasshouse from an infected plant of Cambridge 422.

Transmission tests with the strawberry aphid *Pentatrichopus fragaefolii* (Cock.) in 1951 and 1952 have given negative results. Considering only those tests in which the latent period (judged from graft transmission) has expired, a total of 630 aphids has been transferred from infected to healthy plants. It appears that the strawberry aphid is not a vector of this virus, and other species are now being tested.

COMPARISON WITH OTHER DISEASES

A disease, apparently not caused by a virus, has occurred recently in Louisiana (Plakidas, 1951) with some symptoms resembling those of the green petal disease, which presents several features unlike those of other virus diseases of the strawberry. The flower and fruit symptoms have analogies in Rubus stunt (Prentice, 1950) and blackcurrant reversion (Amos and Hatton, 1927), but the post-fruiting collapse is unique among virus diseases of soft fruit, and closely resembles a symptom of Verticillium Wilt. The sporadic occurrence of infected plants and the apparent rarity of plant-to-plant spread along the row is very different from the field pattern of Yellow Edge and Crinkle. These features, considered together with its occurrence in runner beds isolated from commercial strawberry fields, suggest that the green petal virus is being spread from some other crop or weed by a vector with habits different from those of the strawberry aphid. Because of its severe effect, particularly on Climax, the green petal disease must be considered one of the most potentially serious diseases of strawberries, despite its comparative rarity at present.

Thanks are due to Mr. E. Yoxall Jones for the photographs.

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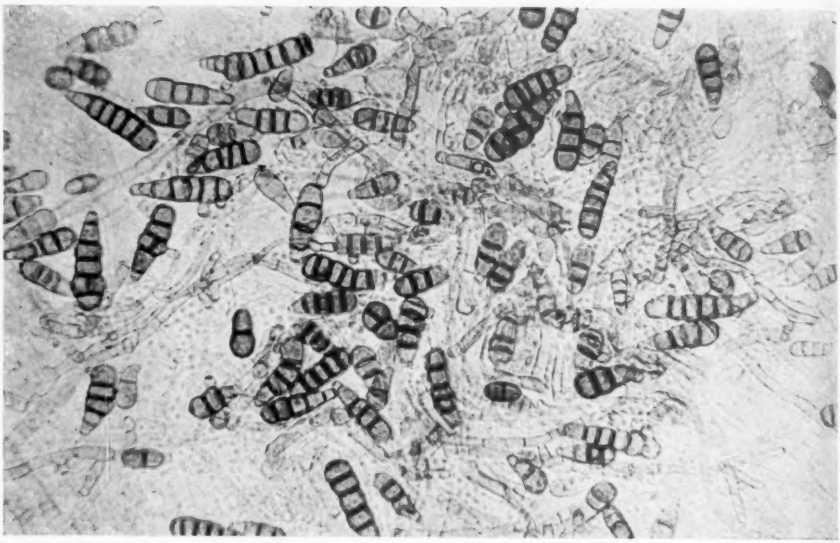
1. Normal flower (above), infected flower (below), and seedy fruit and partially sterile flowers (right).

2. Infected plant in August, showing persistent inflorescence and small young leaves. Healthy plant on right.

Photos : East Malling Research Station

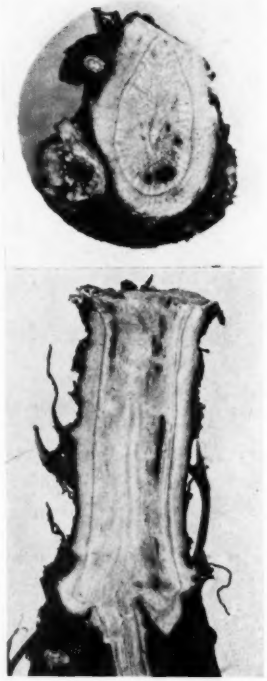
PLATE I

[36251] A***



1. Photomicrograph of spores of *Alternaria brassicicola* Wiltshire. × 300

2. *Left:* Wire-stem effect, healthy and affected seedling.
3. *Right:* Characteristic necrotic streaks and spots on the cotyledons and stem of an infected seedling.

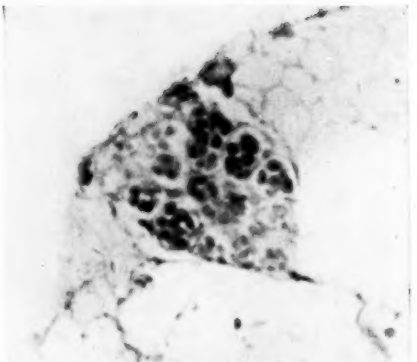


1. Tap root of lucerne infected with *Corynebacterium insidiosum* showing discoloured peripheral wood.
Top : × 2½ *Bottom :* × 2½

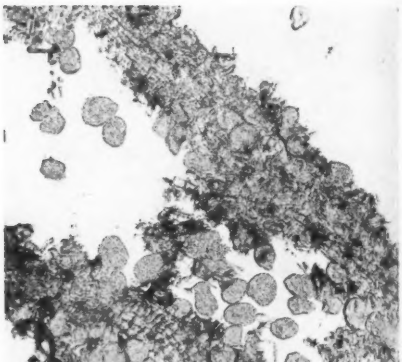
2. Tap root of lucerne infected with *Verticillium albo-atrum* showing discoloured central wood.
Top : × 3 *Bottom :* × 1½

3. *Left :* Uninoculated control plant. *Right :* Plant inoculated with *Verticillium albo-atrum* showing withered leaves and stunting.

PLATE III



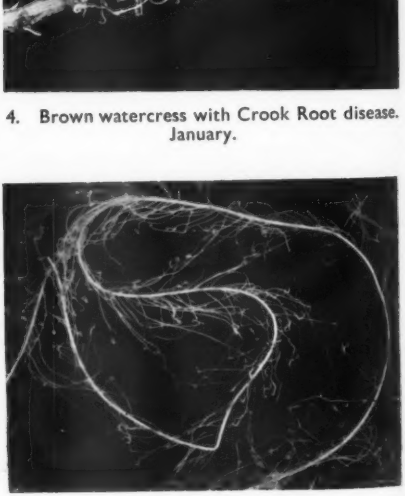
1. Section of infected primary root showing germinated and ungerminated zoosporangia. December.



2. Spore balls from squashed primary root. June.

3. Healthy brown watercress. February.

4. Brown watercress with Crook Root disease. January.



5. *Right*: Distorted secondary roots swollen near the tip. June.

PLATE IV

CROOK ROOT OF WATERCRESS

by D. M. SPENCER

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AND H. H. GLASSCOCK

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In Great Britain, watercress is cultivated in beds of divers types ranging from the slightly modified basins of natural streams to groups of concrete-bordered baths fed by water from artesian wells. Beds are to be found in many parts of the country, but the greatest concentration is in the southern counties, particularly Hampshire. The total area of watercress under cultivation is not precisely known but it was recently estimated (Howard, 1947) as 600 acres, with an average annual yield of 6,000 tons. Within the last decade growers have reported decreasing yields, with a reduction of as much as 30 per cent in some areas and even complete failure of individual beds. In order to ascertain the cause of loss, a survey of watercress beds was begun in the autumn of 1949 and continued until spring 1951 (Spencer, 1951 and 1952).

SYMPTOMS

During the period of the survey it was seen that the plants in affected beds began to lose vigour between October and December, and gradually or rapidly deteriorated so that there was little or no growth for harvesting in January and February, when watercress is in greatest demand and when its monetary value is highest. Associated with loss of vigour was chlorosis and yellowing of young leaflets, sometimes with the margins curled downwards and inwards. Growth was retarded or ceased altogether while, in extreme instances, the underwater parts of the stem became rotten so that the plants lost anchorage and floated away in the water current.

Foliar symptoms were invariably accompanied by changes in root shape. A healthy plant possessed at each node about six to twelve primary roots, 2–4 inches in length (Plate IV, 3). When an affected plant was examined in autumn or winter, the primary roots were either absent, or reduced in length and distorted (Plate IV, 4). Typically, there was at each node only two or three roots each about 0·25 inches in length, and without secondary roots. These roots were swollen, curved and brittle. This peculiar distortion has been noted by growers and other workers and has been given the names " Crook Root " or " Curly Root ". From about April onwards those plants which had remained anchored recovered. Secondary roots were also produced in profusion, but instead of the white flexible rootlets seen in healthy plants, they were creamy brown in colour, swollen near the tip, and rarely exceeding 0·25 inches in length (Plate IV, 5).

THE FUNGUS

Two distinct types of fungal body were found in the tissues of distorted roots, and these are tentatively regarded as aggregates of zoosporangia (Plate IV, 1) and spore balls (Plate IV, 2) respectively. They are presumed to belong to a member of the order Plasmodiophorales. Zoosporangia were found to preponderate

in the distorted primary roots during autumn and winter, while spore balls were most common in the swollen tips of secondary roots in spring and summer.

The release of zoospores was readily demonstrated, but spore balls were never observed to germinate. Infection of healthy roots under laboratory conditions was found to be governed by intensity of daylight ; during spring and summer months, shading from direct sunlight was necessary for successful inoculation. Also, during July, August and September, few roots were produced from shoots in the laboratory or in watercress beds ; this retardation may have been associated with flowering.

Using diseased primary roots as inoculum, plasmodia and zoosporangia were produced in young primary roots which had been developed from axillary shoots of healthy watercress. Before secondary rootlets could be developed in the laboratory it was necessary to shut out light from the underwater parts of plants which had already produced healthy primary roots. In secondary roots the inoculum produced spore balls. By the production of zoosporangia and spore balls from the same inoculum, it was demonstrated that the two forms were different stages of the same fungus. Under laboratory conditions, zoospores were liberated from the newly-formed roots of the test plants eight days after the inoculum was introduced. The few days in which this cycle was completed would account for the rapidity with which every part of a commercial bed may become infected.

Reductions in yield of watercress were sometimes attributable to weeds, pests and nutritional disorders, and possibly to virus diseases, but these appeared to be insignificant compared with losses directly due to the Crook Root fungus.

VARIETAL RESISTANCE

The two types of watercress (Howard, 1947) under cultivation—the " green " and the " brown "—are classified by the respective colours of their leaves as seen in winter and spring ; at other seasons the foliage of both types is usually green. Within each type there are growers' own selections which may be regarded as different varieties. Green watercress (*Nasturtium officinale* R. Br.) has an upright habit ; it is diploid and produces abundant seed. Its growth is more vigorous than that of the brown type, which tends to spread over the surface of the water. Brown watercress is a triploid hybrid resulting from the cross *N. uniseriatum* Howard & Manton × *N. officinale* R. Br., the former being tetraploid. Brown cress sets very little viable seed.

Field observations had indicated that the growth of green cress was less affected by Crook Root disease than was brown cress. The results of a field trial gave support to these observations. In September 1950, strips of green cress were planted among plots of brown cress in a watercress bed which had been regularly infected for at least the three preceding years. Within four weeks most of the roots of both types showed normal symptoms of the disease, but whereas the green cress continued to develop new roots fairly rapidly, the brown cress produced few roots, and by November the green cress was markedly taller and denser. This increase in height and general vigour was maintained until early spring, the time of first harvesting of a healthy crop. At about the same time, the stunted brown cress began to throw out roots and to resume growth, but the early check had delayed its suitability for harvesting by several weeks.

CONTROL

In considering means of controlling Crook Root disease, the application of a suitable fungicide to watercress beds is an obvious choice for experiment. But it is unlikely that a fungicide can be applied with maximum effectiveness until the complete life history of the pathogen is known. Further, water flows through a bed at the rate of 200,000–500,000 gallons per acre every 24 hours. This means that if the water of a bed is to be continuously charged with a fungicide, there will be much wastage and the plants may themselves take up toxic quantities of the substance. Also, the outflow of beds often contributes to streams containing fish.

No quantitative experiments with fungicides have yet been done but pilot tests with calomel and metallic copper (substances chosen for their low solubility) were carried out in a commercial bed. Under the conditions of the experiment these substances did not apparently influence the degree of infection of plants in their immediate vicinity.

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DAMAGE TO ANEMONES BY FIELD MICE

by H. C. WOODVILLE

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Anemones grown for cut flowers in Devon and Cornwall sometimes suffer severe damage by mice, which take the flower-buds by cutting through the stem just above the involucral leaves (" the parsley "), or, in the early part of the season, by cutting through the bend of the flower-stem. The buds are usually stored by the mice in fairly deep holes in the hedge banks, but sometimes they are collected into heaps in the rows under any slight cover. Later on, the mice may eat out the centre of the flower, i.e., the gynoecium and stamens, by way of a neat hole in the petals.

As the flower-buds are so frequently hidden by the mice, growers do not notice the loss until they realize that the number of flowers picked is less than expected. Examination of the crop then shows the cut flower stems, and search brings to light the stored buds. The financial loss can be considerable—in one instance it was estimated at £250 on a quarter of an acre. On beds planted about mid-June, for picking from November onwards, the mouse damage appears to start about mid-November and to cease at the beginning of January. Beds planted later, for picking in the new year, seem seldom to be attacked.

TRAPPING EXPERIMENTS

During the period from October 1950 to January 1951 trappings were made in a field of eight acres on a horticultural holding near Dawlish, in Devon. The trapping area was at the north-east end of the field, and consisted of three lengths of hedge bank, in all 470 feet, on which fifty break-back, treadle mouse-traps were evenly spaced. The crops in the area bounded by the traps were gooseberries, anemones and brussels sprouts. The hedge banks varied in height from two to five feet, with a high hedge on top, which served as a windbreak.

The animals caught were the Wood Mouse, *Apodemus sylvaticus sylvaticus* (L.), the Short Tailed Vole, *Microtus agrestis hirtus* (Bellamy); the Bank Vole *Clethrionomys glareolus* (Miller); the Common Shrew, *Sorex araneus* Jenys; the Pigmy Shrew, *Sorex minutus* L., and the Water Shrew, *Neomys fodiens bicolor* (Shaw). The numbers of each species caught in each month from March to December 1951, with the number of nights of trapping and average total catch per night are given in Table 1.

TABLE 1

ANIMALS CAUGHT, MARCH–DECEMBER, 1951

	Apodemus	*Microtus*	*Clethrionomys*	*Sorex*	Total	No. of Nights	Average per Night
March	18	1	21	1	41	8	4·9
April	6	4	2	0	12	7	1·7
May	0	1	0	2	3	6	0·5
June	8	1	6	0	15	4	3·8
July	3	2	7	1	13	7	1·9
August	6	7	11	1	25	11	2·3
September	20	1	16	1	38	9	4·2
October	20	9	6	0	35	16	2·2
November	38	5	6	23	72	24	3·1
December	21	1	6	13*	41	17	2·4

* Includes 2 *Neomys fodiens*

Only two water shrews were caught, both in December; the stream from which they probably came was about 120 yards from the point of capture. The common and pigmy shrews were not considered serious pests: with their omnivorous appetites they might eat some flowers, but their numbers were too small to cause much damage if they did so. The wood mice and the voles made up the bulk of the catch. The main culprit appeared to be the wood mouse, for voles tend to eat the whole flower rather than to take the centre only (Southern, *in lit.* 1952), and in traps set in the actual anemone beds from time to time few voles were caught.

The trapping was done in a number of periods of two, three and four consecutive nights, and the falling off of the catch after the first night is shown in Table 2.

TABLE 2

MICE CAUGHT IN PERIODS OF TWO, THREE AND FOUR CONSECUTIVE NIGHTS

Duration of Trapping	No. of Periods	Total Catch			
		1st night	*2nd night*	*3rd night*	*4th night*
Two nights	16	70	47	—	—
Three nights	4	17	12	5	—
Four nights	7	33	26	7	17

Damage to Anemones by Field Mice

In March 1951, the average catch (all species) per night was 4·9, due partly to a first night catch of 20. In April, the average dropped to 1·7. The high catch of the first night could be regarded as a removal of the " resident " animals. Assuming that with *Apodemus*, unlike *Mus musculus* and *Rattus* spp., there is no trap shyness, a drop in numbers caught represents a real drop in the population. But breaks in the trapping allowed the population to build up through migration into the trapping area. In fact, the figures for average nightly catch remained fairly constant over the whole period. The surrounding fields were all under farm crops, and as they were small there was a relatively great area of hedge banks in the neighbourhood capable of providing food and shelter for a very large mouse population. The results of the trappings indicated that the number of mice being caught was small compared with the total population, and that they were being caught at about the same rate as they migrated into the trapping area. The trapping was therefore quite ineffective as a control measure.

TRIAL WITH POISON BAIT

In November 1951, baiting was carried out along both sides of a lane at the north end of the field while trapping continued inside the hedge. The bait was made from sausage rusk and molasses, the molasses being diluted with the same volume of water, and one volume of this dilution mixed with two of rusk. This made a crumbly bait which was taken freely. After pre-baiting for four nights, poisoning was done with 5 per cent zinc phosphide in the same bait (Roebuck *et al*, 1944). Table 1 shows that there was little reduction in the total number of animals caught after the poisoning but that the proportion of voles to mice was considerably reduced, the mean proportion being 116 : 100 before the poisoning and only 29 : 100 afterwards. From the takes of bait and poison the operation appeared to have been fairly successful, so that the explanation of the results was to be sought in the differing home ranges of the mice and the voles. *Apodemus* has a very wide range, up to 400 yards per night (Evans, 1942), so that when all the mice have been killed off in an area it can soon be re-invaded. The voles have only a short range (Evans, 1942) so that it will take much longer for them to move into the space provided. In fact, it was not until 10–15 days after the poisoning that voles were being caught, whereas *Apodemus* was caught after 3 days. This suggests that while voles can be controlled fairly easily, *Apodemus*, the real pest, would have to be cleared from so large an area that the operation would not be economic.

At present the only adequate measure of control appears to be the use of wire netting. This should be of half-inch mesh ; the bottom should be dug in, and the top curved out and down to prevent mice from climbing over it. If the netting is put up well and the lengths are joined carefully, it proves very successful, and with care will last for a good many years.

ATTACK IN RELATION TO BODY WEIGHT

Examination of trapped mice showed that in December there is a rapid increase of body weight, and that this rises to a maximum in May and June (Table 3). This was in accordance with the findings of Hacker and Pearson (1944).

TABLE 3

BODY WEIGHT OF APODEMUS SYLVATICUS

	MALES		FEMALES	
	Number Examined	Average Weight	Number Examined	Average Weight
		grams		*grams*
October 1950	16	15·3	17	14·5
November	23	15·4	32	16·0
December	24	17·9	27	17·7
January 1951	12	19·9	33	18·1
February	7	21·0	12	17·6
March	10	25·0	13	18·2
April	8	22·5	3	19·6
May	2	20·0	3	23·3
June	7	23·4	6	21·1
July	4	21·5	1	21·0
August	5	16·6	2	14·5
September	13	18·9	12	17·2
October	13	15·1	7	14·7
November	20	14·5	27	15·7
December	7	14·4	14	16·0
January 1952	7	18·0	11	17·4

The start of the increase of growth coincides with the start of the attack on the anemones. The central portions of the flowers, as eaten by the mice, were analysed by C. D. Rickaby, who found that their crude protein content was 5·31 per cent of the wet material, or 43·5 per cent of the dry weight. A food so rich in protein would be of value to the mice at a time of rapid body growth. Muller (1952) has pointed out, moreover, that the attack coincides with the end of the breeding season, and that at this time one of the activities of the mice is the collection and hoarding of food. No reason could be found for the lack of damage to the late planted beds at the same period. Flowers were present in them, though not in large numbers. The plants were smaller, and would not afford so much shelter as those sown earlier.

Thanks are due to Mr. D. C. Thomas for his helpful suggestions in this work; to Mr. C. D. Rickaby for the analyses; and to Mr. H. Whetman, of Houndspool Nurseries, for permission to carry out the trapping on his land.

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STUDIES OF CABBAGE APHID INFESTATIONS ON BRUSSELS SPROUTS, 1951

by A. IBBOTSON

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Surveys were made on a number of crops of Brussels sprouts in the south-west of England in 1951 to explore the relationships between the distribution of *Brevicoryne brassicae* L., the condition of the plants, the degree of infestation, and the character of the fields. The work was a part of that promoted by the Pest Assessment Committee of the N.A.A.S. Conference of Advisory Entomologists, and is supplementary to that already described in this JOURNAL by Empson (1952). An intensive survey of five fields and an extensive survey of twenty fields were made.

In the intensive survey, counts were made at fortnightly intervals from mid-August to the end of October of numbers of live and visibly parasitized aphids, and of predatory larvae on each of fifty plants in two diagonal traverses of each field. The leaves on each plant in the first traverse were sub-divided into classes according to size, and the number and size of the colonies on them was separately recorded for each class. The amount of infestation of the sprouts was recorded in October.

In the extensive survey, observations were made in September or October only, and were confined to the amount of infestation of the sprouts. The infestation of each of twenty-five plants in a diagonal traverse of the field was assessed as " clean ", " slight ", " moderate " or " heavy ", according to the scale already given by Empson (1952).

In both the intensive and the extensive surveys, particulars were recorded for each field of : planting date ; type of agriculture within five miles ; general topography—whether hilly or flat ; local topography of the field—whether sloping, flat, in a hollow or on a summit ; the field aspect if on a slope ; the altitude ; the degree of shelter ; the soil type ; the area of the field and of the crop ; and the direction of the traverse or traverses.

DISTRIBUTION OF APHIDS ON BRUSSELS SPROUT PLANTS

As the Brussels sprout plant increases in size it puts out new leaves which reach maturity in succession. At first they are tightly curled and pale in the centre of the terminal bud, but as they age they straighten out, expand and darken. The first leaves to reach maturity are smaller than those which mature later. When the sprouts begin to form, growth of the crown leaves slows down and there is an increase in the senescence rate of the lower leaves ; these go yellow progressively up the stem as the sprouts develop. The lower leaves are easily pulled off when in this condition, and most of them are stripped from the plants when the sprouts are picked for the first time.

When the aphids were first recorded the plants had about thirty leaves each, all of which were green. These were classified into groups according to their size relationships as shown on page 26, and the same method of classification was used in later recordings.

KEY FOR CLASSIFICATION

Y Young leaves. Leaves in the bud ; yellow, brittle and tightly curled over each other.

YM Immature leaves. The upper fifth of the expanded leaves. Completely unfolded ; each leaf much larger than the preceding one in the group.

M Mature leaves. The middle three-fifths of the expanded leaves. Apparently fully grown, and all about the same size.

MO Old leaves. The lower fifth of the expanded leaves at the base of the plants.

About three-fifths of the leaves on each plant were classified as mature on each occasion of inspection, and since they were always the largest of the leaves, they comprised about three-quarters of the total leaf-area. The actual measurements of the leaves on a typical plant when the sprouts were just forming are shown in Fig. 1.

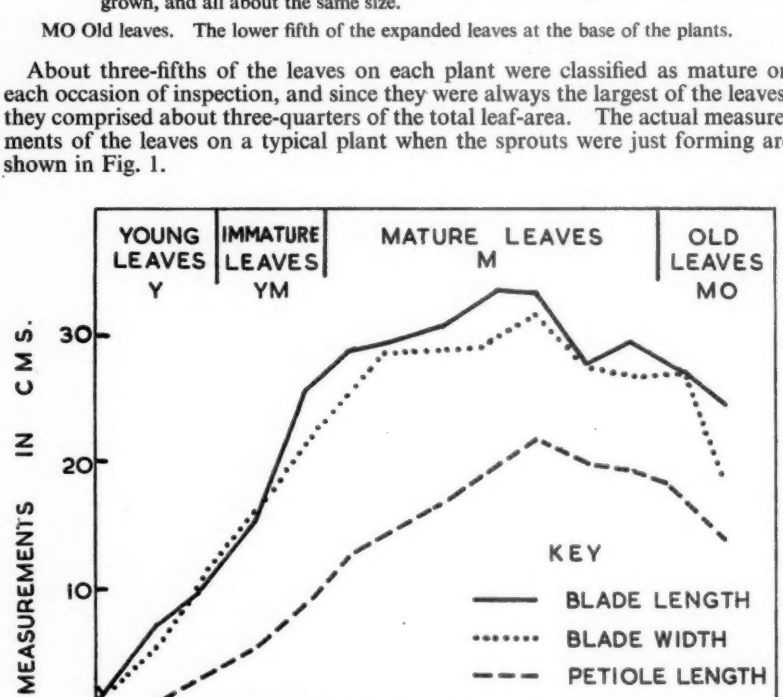


Fig. 1. Measurements of every fourth leaf on a typical Brussels sprout plant in September when sprouts were first forming.

The aphids were always found in isolated colonies. As few solitary aphids were found at any time the colonies must have retained their identity for a considerable period, and those which were large were likely to have been in existence longer than the smaller ones. Thus the best indication of leaf-suitability for colony founding was the presence of colonies consisting of an adult and a few young, and, in particular, of colonies in which the adults were alate, as this form was easy to distinguish from the older nymphs. Such " index " colonies were recorded separately. Others were classified according to the number of aphids visible on inspection ; the area of leaf occupied by 5, 10, 50 and 100 aphids respectively being noted, and the colony size estimated according to the total area covered by the aphids. Categories used for the

recording of colonies were : " recent "—0 to 50 aphids ; " established "—50 to 1,000 aphids ; and " extensive "—over 1,000 aphids.

On August 28, a number of lesions were found which appeared to have been caused by aphids, although there were no signs of old skins, dead bodies or aphid detritus. When some of the tissue from these lesions was examined in the laboratory it was found to be identical with that on which aphid colonies had been ; that is, the mesophyll had thickened and the intercellular spaces, particularly in the palisade tissue, were filled with air bubbles. It seemed likely that these were lesions that had been deserted by the aphids, for many of them were found beneath leaves where the aphids would have been protected from the weather, and in fields where parasites and predators had not yet appeared. The distribution of lesions, of about, or more than, the area of a shilling, with and without aphids on them, was therefore recorded in the intensive survey on September 3.

TABLE 1

NUMBER OF APHID LESIONS AND COLONIES ON EACH GROUP OF LEAVES (September 3)
(The counts shown are for 50 plants in each field.)

	Young Leaves		Immature Leaves		Mature Leaves		Old Leaves	
	L	*C*	*L*	*C*	*L*	*C*	*L*	*C*
Field I	0	20	26	33	32	12	0	0
Field II	0	12	25	40	39	30	0	0
Field III	0	4	12	3	6	1	0	0
Total ..	0	36	63	76	77	43	0	0

L = Vacant lesions C = Colonies

Table 1 shows that the total number of lesions and colonies was about the same on the immature as on the mature leaves, thus indicating that few new colonies were formed on the leaves once they were mature. There were nearly as many vacant lesions on the immature as on the mature leaves, and this suggested that most of the colonies dispersed or disappeared as the leaves were reaching the immature stage, i.e., as they were unfolding from the bud. Thus, up to September 3, the terminal bud seems to have been preferred for colony founding, and a large proportion of the colonies dispersed as the leaves became older.

TABLE 2

NUMBER OF APHID COLONIES ON YOUNG, IMMATURE, MATURE AND OLD LEAVES
(Total for 50 plants in each of 5 fields.)

Date of Visit	Index Colonies				Recent Colonies				Established Colonies				Extensive Colonies			
	Y	*YM*	*M*	*MO*	*Y*	*YM*	*M*	*MO*	*Y*	*YM*	*M*	*MO*	*Y*	*YM*	*M*	*MO*
Aug. 12	5	0	0	0	11	8	0	0	1	3	1	0	0	0	0	0
Aug. 28	6	5	0	6	33	52	4	14	3	11	17	1	0	2	0	0
Sep. 13	0	85	457	15	7	164	146	15	1	11	27	2	0	2	8	1
Oct. 4*	1	7	143	4	4	5	366	30	2	3	41	6	0	1	8	1
Oct. 28†	0	0	0	0	3	1	65	0	1	1	14	7	0	1	8	1

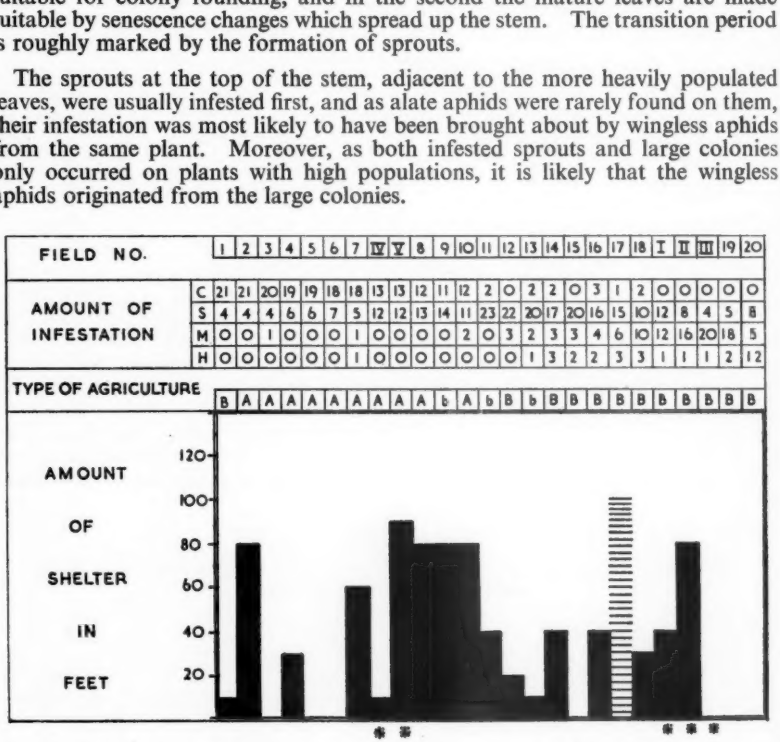
* Terminal buds removed from all plants on two of the fields a few days before this visit.
† First picking of sprouts with stripping of lower leaves just before this date.

The total numbers of the four types of colony on the plants examined in the five fields in the intensive survey (Table 2) give similar indications. Only a small proportion of the " index " and " recent " colonies were found on the

mature leaves before September 13. The occurrence of a high proportion of " established " and " extensive " colonies at the later dates must have been due to a carry-over of colonies on leaves which had become mature, rather than to an increase in the size of the colonies established on mature leaves from the first. On September 15 and after, a large proportion of the " index " and " recent " colonies, by now being formed by alate originating from the " established " and " extensive " colonies, were on the mature leaves. These appeared to have become more susceptible to attack on ageing but before visible senescence.

These records therefore point to the occurrence of the same phenomena with *Brevicoryne brassicae* on Brussels sprouts, as Kennedy, Ibbotson and Booth (1950) found with *Aphis fabae* on sugar beet ; namely, that young leaves and those which are senescing are the most suitable for colony formation. The course of the infestation of the Brussels sprout plant can apparently be divided into two distinct phases : in the first only the bud and immature leaves are suitable for colony founding, and in the second the mature leaves are made suitable by senescence changes which spread up the stem. The transition period is roughly marked by the formation of sprouts.

The sprouts at the top of the stem, adjacent to the more heavily populated leaves, were usually infested first, and as alate aphids were rarely found on them, their infestation was most likely to have been brought about by wingless aphids from the same plant. Moreover, as both infested sprouts and large colonies only occurred on plants with high populations, it is likely that the wingless aphids originated from the large colonies.



Amount of infestation .. C = Clean, S = Slight, M = Medium, H = Heavy

Type of agriculture .. B = Intensive brassica-growing area, b = Borders of brassica area, A = Isolated fields

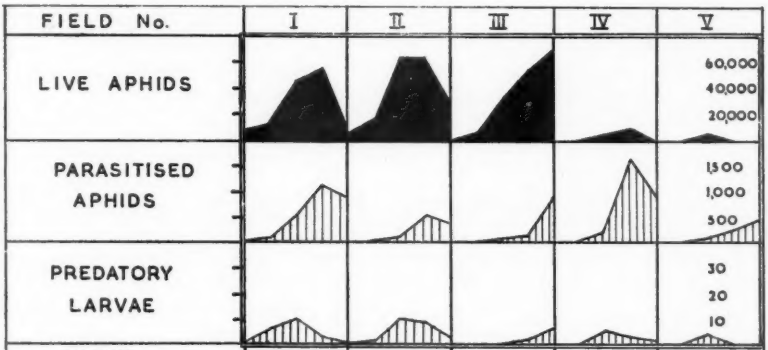
Shelter .. .. Sum of average hedge heights in N, S, E and W quadrants of field. The shaded column refers to a young orchard.

Fig. 2. Type of agriculture and amount of shelter of each field in the extensive and intensive survey arranged in increasing order of infestation.

APHID POPULATIONS AND INFESTATIONS IN FIELDS

When the observations made in the extensive survey were arranged according to the amount of infestation of the sprouts (Fig. 2), the fields could be divided into distinct groups. The heavier infestations occurred on fields in the intensive brassica-growing areas, and the lighter ones on fields which were isolated ; within these divisions (apart from the three most heavily infested fields) those with the heavier infestations were generally the most sheltered. There was no obvious relationship between the amounts of infestation and any of the other field characteristics recorded.

The counts of live aphids, parasitized aphids and predatory larvae in relation to the amount of infestation and to environmental factors, for the five crops studied in detail in the intensive survey, are shown graphically in Fig. 3. There were many more aphids in Fields I, II, and III than in IV and V. At the first visits there were not many more aphids on III than on IV and V, but at the last visit the aphid population on III was still increasing, while in all the others it had fallen. There were more parasitized aphids in Fields I and IV than in the others, while in Field III parasites did not appear until very late in the season.



* Sheltered by topographical features, rising ground, etc.

Fig. 3. Numbers of live aphids, parasitized aphids and predatory larvae (Syrphids) found at each visit, for each field in the intensive survey, with corresponding infestation and environmental data. For dates of visits see Table 2.

Fields I, II and III were situated in the heart of an intensive brassica-growing area in north Gloucestershire, and this probably accounts for their high populations of aphids, as the availability of migrants would be high throughout the season. Fields IV and V, one in Wiltshire and the other in south Gloucestershire, were isolated from other brassica crops, apart from those in scattered cottage gardens, by at least three miles in every direction.

Fields I and II were in tree-sheltered hollows, while III was very exposed near the summit of a convex slope completely devoid of cover. This probably accounted for the widely differing development of the aphid populations between Field III and Fields I and II.

This exposure may have contrasting effects, on the one hand restricting and delaying the settling of migrants so that the aphid population is potentially low, and on the other, restricting the effective development of parasite and predator populations so that subsequent multiplication of the aphids is virtually unchecked.

Differences in both the number and conditions of the aphid populations were reflected in the differences between the amounts of infestation of the sprouts. These were not infested at all in Fields IV and V where the aphid populations were low ; they were fairly heavily infested in Fields I and II where the populations were high but fell before the last visit ; and most heavily infested of all in Field III where the aphid population built up late owing to the absence of parasites and predators.

The results of the two surveys indicate that the amont of infestation of the sprouts is determined no less by the activity of the parasites and predators than by the abundance of aphids, and that both these factors depend upon the exposure of the fields and the abundance of brassica crops in the locality.

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F.A.O. PLANT PROTECTION BULLETIN

The Food and Agriculture Organization of the United Nations now publish a monthly bulletin, with the above title, for the dissemination of information received by the World Reporting Service on Plant Pests and Diseases, in accordance with the provisions of the International Plant Protection Convention, 1951 (see *Plant Pathology*, 1952, **1**, 14). The bulletin contains articles of great interest and international importance on the occurrence, outbreak and control of major pests and diseases throughout the world. Manuscripts should be addressed to Dr. Lee Ling, Plant Production Branch, Agriculture Division, F.A.O., Rome ; and subscriptions (30*s*. per annum) to Document Sales Service, F.A.O., Viale delle Terme di Caracallo, Rome. Volume I, Part 1, was issued in October 1951.

VERTICILLIUM WILT OF LUCERNE IN BRITAIN

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During the examination of a five-acre field of lucerne (*Medicago sativa* var. Grimm) near Edinburgh in July 1950, Dr. W. A. F. Hagborg of Winnipeg pointed out that many of the plants exhibited the symptoms of bacterial wilt due to *Corynebacterium insidiosum* (McCulloch) Jensen (Jones and McCulloch, 1926), with which he was well acquainted. Patches of lucerne had died out, or were stunted, with small, white, withered leaves showing severe wilting; on digging up some of these plants and cutting across the tap roots just below soil level, the woody cylinder was observed to be discoloured. All these symptoms are characteristic of bacterial wilt as it occurs in North America (western states of the U.S.A. and western provinces of Canada), and as this disease had not been recorded in western Europe, the discoloured roots were examined at Edinburgh and at Cambridge for *C. insidiosum*.

After washing in water, fragments and thin sections of the roots were plated out on yeastrel-glucose agar. From many of them a yellow bacterium grew out and from all of them the hyphae of a fungus. Both fungus and bacterium were readily obtained in pure cultures. The morphological characters and staining reactions of the bacterium corresponded with those of the genus Corynebacterium; but as the blue pigment so characteristic of *C. insidiosum* was never produced on carbohydrate media it was considered to be either a non-pigmented strain of this species or one of the numerous species of soil saprophytes of the same genus (Jensen, 1934). The bacterium was subsequently identified as *C. helvolum* (Zimmerman) Kisskalt & Berend. The fungus was readily identified as *Verticillium albo-atrum* Reinke & Berth.

INOCULATION EXPERIMENTS

Inoculations with isolates of the fungus were carried out at the end of April 1951 and repeated in 1952, using lucerne plants about six months old. These were transplanted into three-inch pots containing unsterilized John Innes seedling compost (Lawrence and Newell, 1939) to which about one-third by volume of a month-old culture of the isolated fungus, in 3 per cent corn-meal-sand, was added. In 1951, 12 pots were inoculated and 12 retained as controls; in 1952, 6 were inoculated and 6 retained as controls. Symptoms were first observed in the inoculated plants in about one month, and all inoculated plants showed symptoms in five weeks. The tops of the plants were first observed to wilt on warm days and recover in the evening. A few days later, the lower leaves wilted in acropetal succession, rapidly turning pale, then yellow, and finally white; they were then quite desiccated. Eventually the first shoot died completely; basal shoots grew up apparently healthy only to repeat the process. *Verticillium albo-atrum* was recovered from wilted shoots of all inoculated plants to a height corresponding to the last wilted leaf but not higher; in completely dead shoots the fungus could be isolated from the tip. In 1951, four of the control plants, contiguous to those inoculated, developed symptoms about two months after the experiment was set up, probably infected by soil

splash. In 1952 the control pots were well isolated from the treated pots and no infection developed. The inoculated plants were stunted as compared with the controls (Plate III, 3). Similar results were obtained in earlier experiments in which a water suspension of *Verticillium* spores mixed with *Corynebacterium helvolum* was poured over the crowns of young plants. During 1951, *Verticillium albo-atrum* was again isolated from wilting lucerne plants grown in Essex and Norfolk.

Verticillium albo-atrum can therefore cause a wilt disease of lucerne with symptoms remarkably like those of bacterial wilt. Although it is known to attack many different plants in America and Canada as well as in Great Britain and the Continent, we have found but three records of a lucerne wilt caused by this fungus. It was first recorded in Germany by Richter and Klinowski (1938), whose description and illustration of the brown discolouration of the tap root correspond closely with those found in the present investigation. It was again reported a few years later from Germany by Richter (1941); and from Denmark by Hansen and Weber (1948).

COMPARISON OF VERTICILLIUM WILT AND BACTERIAL WILT

In order that a direct comparison might be made between the symptoms of the two diseases, simultaneously with the Verticillium inoculations young plants in pots were inoculated with *Corynebacterium insidiosum* in April 1952 and placed on the roof of the Botany School at Cambridge, with strict precautions to prevent the spread of the pathogen. As the bacterial wilt is severe only on well-irrigated land in Canada (Alberta), those inoculated with the bacterium were stood in a tray of water. *C. insidiosum* was introduced in two ways : by adding a strong suspension in water to the soil after severing some of the roots ; and by applying drops of a similar suspension to the stumps of cut-off shoots (in Canada some infection is known to take place after mowing). Both sets of plants inoculated with the bacterium wilted, but there were quite marked differences in the symptoms exhibited by the plants infected with *V. albo-atrum* and those infected with *C. insidiosum*.

The plants inoculated with the bacterium did not show any wilting until two months or more had elapsed. Moreover, whereas the Verticillium-inoculated plants exhibited a progressive wilting of the leaves commencing from the base of the shoots and progressing upwards, the leaves of the bacterium-inoculated plants wilted all at once, the leaflets turning yellowish and becoming white and " papery ". During the course of the summer both sets of plants sent up new and apparently healthy shoots.

In July 1952, the roots of one plant of each set were examined by first washing and then cutting across the base of the tap root. Discolourations were marked in both ; but were not identical. *Verticillium albo-atrum* had produced a dark brown stain and gum in the more central parts of the woody cylinder (Plate III, 2), while *Corynebacterium insidiosum* had formed an incomplete ring of dark grey stained vessels towards the outer edge of the wood (Plate III, 1), and also grey flecks on the cambium layer revealed by peeling off the cortex. Both the grey discoloured ring and cambium are characteristic of invasion by *C. insidiosum* as recorded in North American descriptions and observed by one of us (W.J.D.) in Alberta, while the browning and gumming of the more central vessels is quite characteristic of invasion by *Verticillium albo-atrum*. From the discoloured wood of one of the bacterium-inoculated plants *C. insidiosum* was recovered. At the conclusion of the work all plant material was burned and the soil sterilized.

CONCLUSIONS

From our observations it is evident that a wilt disease of lucerne caused by *Verticillium albo-atrum* occurs in Scotland and East Anglia, characterized by successive wilting of the leaves from below upwards, and accompanied by a brown discolouration of the central portion of the woody tap root, which becomes more extensive as the disease progresses. The wilting leaflets curl inwards, turn yellow and finally become white and dry. In subsequent years the affected plants become more stunted with small yellowish foliage. The Verticillium disease can be distinguished from the very similar bacterial wilt of North America by the more sudden wilting of the foliage in the latter disease, in which the discoloured wood of the tap root is in a ring, and grey rather than brown. Moreover, in the bacterial wilt the cambium layer is also discoloured grey in flecks and streaks—a symptom which is obvious on peeling off the cortex. No such discoloration has been observed in the cambium layer of plants attacked by Verticillium.

There is no evidence that the bacterial wilt of lucerne due to *Corynebacterium insidiosum* occurs in Britain.

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ERGOT IN WHEAT VARIETY TRIALS IN HERTFORDSHIRE

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For a number of years the Institute has been carrying out a series of combined variety and manurial trials of winter wheats. The varieties are drilled in strips side by side, in the form of a randomized block, at several different centres in the county. The plots are not usually replicated at any one centre but, for the purpose of statistical analysis, all the centres are considered to constitute a single experiment (Yates and Cochran, 1938). For the manurial trial each strip of each variety is divided into three sub-plots, and three nitrogen treatments are randomized among them. Each sub-plot is harvested separately, so that for each variety there are three lots of grain representing the manurial treatments ; from each lot a sample of about 10 lb. is taken for bread-making and related tests.

In 1952, when taking samples at one of the centres (Buntingford), I noticed an unusual number of ergots, *Claviceps purpurea* (Fr.) Tul., in the grain from some of the plots, and therefore made counts to ascertain whether there was any appreciable difference in the incidence of ergot according to variety or manurial treatment. The wheat at this centre was sown on October 26, 1951, following a clover ley, and harvested on August 26, 1952. The ergots were removed by hand picking from the cleaned sample, which contained most of them, and from the rubbish removed from the samples. There was no apparent difference between the number of ergots in the sub-plots with the different manurial treatments, but the variation according to variety was considerable.

TABLE 1

NUMBER OF ERGOTS PER 10 KILOS OF WHEAT, BUNTINGFORD 1952

Variety	Number of Samples	Mean Number of Ergots per Sample
Cappelle	3	128 ± 11
Vilmorin 27 ..	3	66 ± 12
Holdfast	2	64 ± 18
Nord Desprez ..	3	52 ± 3
Glasnevin Alba ..	2	38 ± 7
N.59	2	35 ± 10
Pilot	3	29 ± 18
Bersée	3	25 ± 2
Scandia	2	20 ± 10
Atle	3	18 ± 4
Little Joss ..	3	15 ± 3
Hybrid 46 ..	3	12 ± 1

It will be seen from Table 1 that there was a definite suggestion of a difference in the susceptibility of the several varieties. The existence of varietal differences in susceptibility to ergot has often been mentioned in the past, for example, by Weniger (1937) and Dillon Weston and Taylor (1943), but there is a lack of information on the relative susceptibility of named varieties, and the figures in Table 1 may indeed be the first of their kind to be published, at any rate for wheats.

Ergot was also present in the wheat at two of the three other trials in Hertfordshire in 1952. Although the number of ergots was very small, they were found chiefly in the varieties appearing as the most susceptible in Table 1.

At Oaklands, for example, where the samples from the varieties Cappelle, Vilmorin 27, Holdfast, Nord Desprez, Atle, Little Joss and Hybrid 46 were examined, Cappelle contained four ergots, Holdfast one, and the remainder none at all. As ergot was present in three out of the four trials in 1952, the disease may be more common in *vulgare* wheats than is generally supposed.

The attack at Buntingford was relatively severe, and as such attacks on wheat do occur occasionally—there was one of similar severity at another of our centres in 1948—their economic significance has to be considered. Ergot at such a level of incidence has little or no effect in reducing the crop—although it has been shown (Seymour and McFarland, 1921) that the injurious effects of the ergot fungus on the plants are not limited merely to the replacement of grains by ergots. There is, however, a possibility of it being of importance to the miller. In this respect, the important criterion is the percentage by weight of ergots. Wheat ergots vary considerably in size, but figures from the bulked sample of all those collected at Buntingford, with normal grain weights for comparison, are given in Table 2. These figures are the means for four weighings ; those for the normal kernels are at 90 per cent dry matter.

TABLE 2

WEIGHT OF WHEAT ERGOTS AND NORMAL GRAIN, BUNTINGFORD, 1952

	Grammes per 100
Ergots	1·65 ± 0·08
Kernels of large-grained wheat (Vilmorin 27) ..	4·95 ± 0·05
Kernels of small-grained wheat (Atle)	3·18 ± 0·03

From Tables 1 and 2 it may be calculated that even the Cappelle at Buntingford contained only 0·02 per cent by weight of ergots, and thus even here there seems little cause for alarm.

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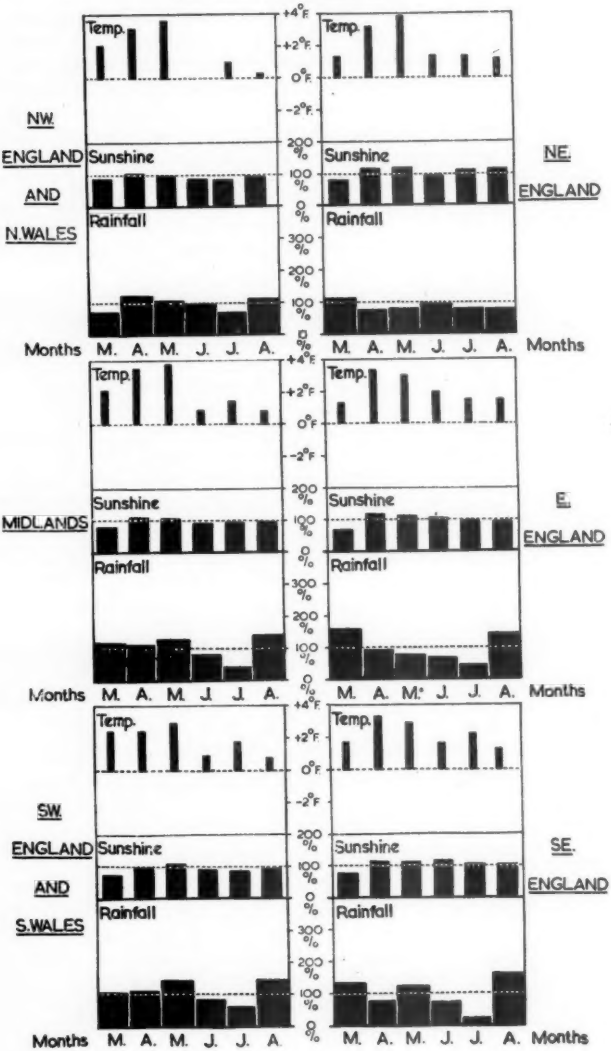
MARCH–AUGUST WEATHER 1952

Variations from average



THE WEATHER OF ENGLAND AND WALES*

SPRING AND SUMMER, 1952

The outstanding feature of the spring of 1952 was the high soil temperature, which remained well above average throughout the season except for a brief spell in the last week of March. During this spell, temperatures were low and substantial falls of snow were experienced, especially in the Midlands. April was generally mild, and a very warm spell occurred from the 16th to the 19th. May was unusually warm and the beginning of the month was wet except in the east and north-east. There was almost a complete absence of late spring frosts.

June was dry in eastern England and wet in the west ; temperatures were high in the last week. July was very dry except in a few scattered areas in the north-west, and an absolute drought prevailed at many places in the southern half of England towards the end of the month. Temperatures remained above average during August, but the weather was very unsettled. Rainfall was very heavy locally at times and some abnormal falls were recorded, such as 2 inches in 30 minutes at Wembley on the 6th, and 9 inches on Exmoor on the 15th.

The weather in each of the six months from March to August (inclusive) is represented graphically on page 36. Figures for six districts of England and Wales are shown in terms of deviation from average for air temperature, sunshine and rainfall. From these graphs the general and persistent warmth of the two seasons is immediately recognizable ; the only occurrence of sub-normal monthly temperature is in June in the north-west. Sunshine values show few outstanding features, but the rainfall values in June and July in the Midlands, east and south-east are conspicuously low. Rainfall totals during these months were lowest in the counties around Bedfordshire.

YELLOW RUST OF WHEAT IN ENGLAND AND WALES, 1952

Yellow Rust, *Puccinia glumarum* Erikss & Henn., was unusually prevalent in most parts of the country in 1952, and the attack was severe on susceptible varieties. In the north-west it was first noticed in a crop of Welcome in April, and in early May was found on other crops of this variety and on Jubilégem ; spread was checked at the end of May. By late July, however, infection was widespread, being frequently severe on Pilot, and in many crops of Jubilégem the glumes were infected. Little rust was recorded in the north-west or North Wales. In the Midlands it was already severe in some crops, chiefly Jubilégem ; in western districts by May. At the end of June many crops of Jubilégem and Nord Desprez were heavily infected, and although the development of the disease was checked in July, infection of the glumes was noted in several crops at the end of the month. In the east the disease was first recorded at Cambridge in March, and by mid-April it was severe on several crops of Jubilégem and Nord Desprez. In this area also, spread was checked at the end of May, but later the rust became widespread throughout the eastern counties and it was particularly

* These notes, and the diagram on page 36 are provided by the Agricultural Branch of the Meteorological Office, and published by permission of the Director.

severe on Nord Desprez with conspicuous infection of the glumes. In the south-west, infection was present in May on crops of Jubilégem and Wilma, but it became prevalent only at the end of July when Nord Desprez was often severely affected.

In work on the physiologic races of *P. glumarum* at the National Institute of Agricultural Botany during the past three seasons, Dr. C. C. V. Batts has found only three races, namely, 2, 5 and 8, in collections from the field. Race 8 has been found in all parts of the country, and the varieties Wilma, Jubilégem and Pilot have been particularly susceptible to it. Race 5 has been found in the north, where it has severely attacked King II. Race 2, as previously reported by Manners (*Ann. appl. Biol.*, 1950, **37**, 187–214) has been present in central and southern England, and Nord Desprez is particularly susceptible to it. From his previous work in Scotland (1943–49) Dr. Batts associates severe attacks with high spring temperatures.

Plant Disease Survey

PREVENTION OF MOULD ON RAT BAITS

One of the most interesting developments in rodent control during the last two or three years has been the use of anti-coagulants such as Warfarin (3–(α–acetonylbenzyl)–4–hydroxycoumarin). Their effectiveness depends on repeated ingestion of small doses over the course of a few days. This may, of course, be achieved by putting down fresh bait each night but a more economical method is to put down at each baiting point sufficient poisoned bait to last for several days, and then " top up " only occasionally.

This raises the problem of how baits in damp situations can be kept relatively free of moulds which, if allowed to grow, would lower acceptance by rats. It is a problem which has always been present in hot, damp climates where baits often become unpalatable after a few hours. The usual answer has been to incorporate in baits a small quantity of vegetable or mineral oil. Vegetable oils, even if they improve acceptance at first, tend to become rancid and quickly reduce palatability. Cage tests indicate that mineral oils are to some extent unpalatable from the beginning. In some quarters also, it is argued that oily baits carry a very slight fire-risk.

Some effort has been made, therefore, to find other anti-mould substances. One of the most promising is para-nitrophenol which has been studied by Doty and his colleagues in the special conditions of the Hawaiian sugar plantations (*Hawaii. Plant. Rec.*, 1949, **53**, 65–73), and which is receiving attention along with other candidate anti-mould preparations in the U.S.A. It has recently been the subject of a number of laboratory and field trials by the Infestation Control Division of the Ministry of Agriculture and Fisheries, partly to discover also whether in some situations damp baits (which are usually more acceptable to rats) can be used instead of dry baits.

Results are as yet incomplete, but they suggest that if para-nitrophenol is eventually recommended it will only be in treating infestations of the common rat, *Rattus norvegicus*. Preliminary tests suggest that its adverse effect on bait acceptance by the ship rat, *Rattus rattus*, is too marked to be overlooked.

Infestation Control Division

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